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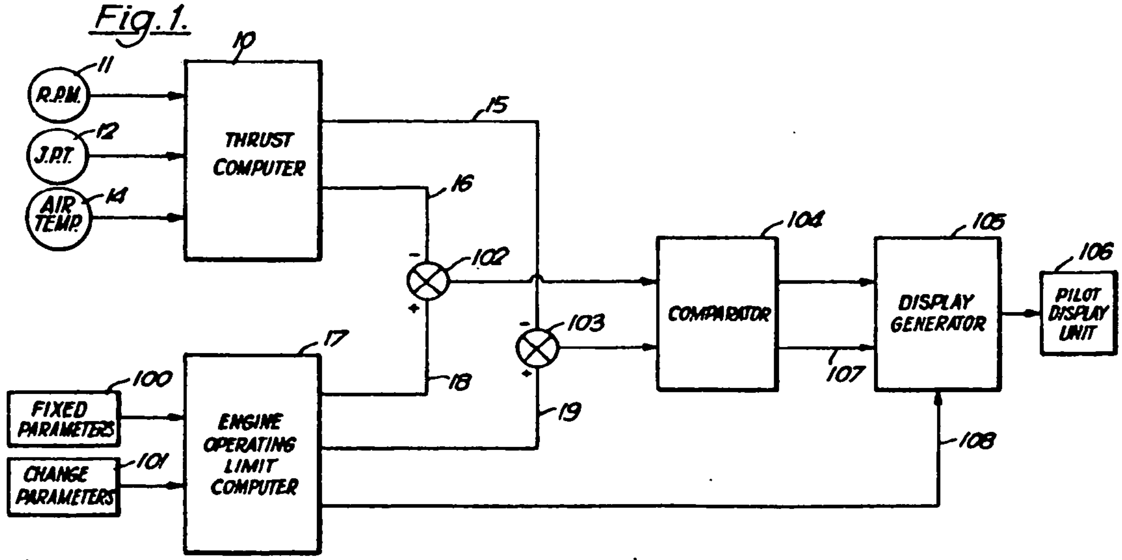
(54) Aircraft instrumentation

(57) In a power margin indicator for a vectored thrust aircraft a thrust computer (10) monitors engine speed (RPM) (11) and engine jet pipe temperature (JPT) (12). Thrust computer (10) computes an actual value of thrust from known relationships between RPM, JPT and ambient air temperature (14) to provide a thrust value output (15, 16). An engine operating limit computer (17) provides outputs (18, 19) proportional to the maximum value of thrust available by computation based on known relationships between fixed parameters (100), and changing parameters (101). Thrust outputs on outputs (18, 19) therefore are set at the limiting value of thrust available with respect to JPT or RPM respectively. Thrust values (15, 16) and (18, 19) are scaled so that a thrust margin may be provided by subtractors (102 and 103) for limiting values of JPT and RPM respectively. The thrust margin values associated with each parameter are directly compared by comparator (104) and the valve closest to its limiting value (that is the lower thrust margin value) passed to display generator (105) for onward transmission to pilot display unit (106).

Fig. 1.



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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Fig.3a.

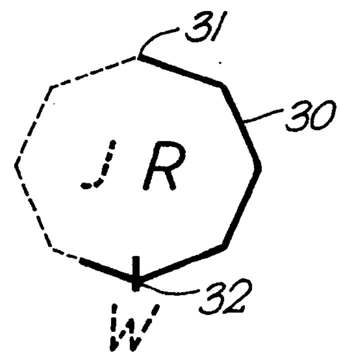


Fig.3b.

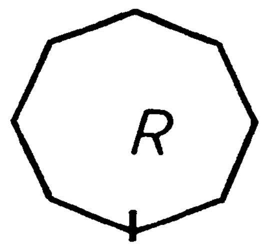


Fig.3c.

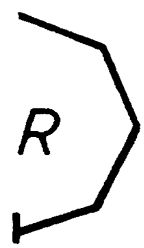
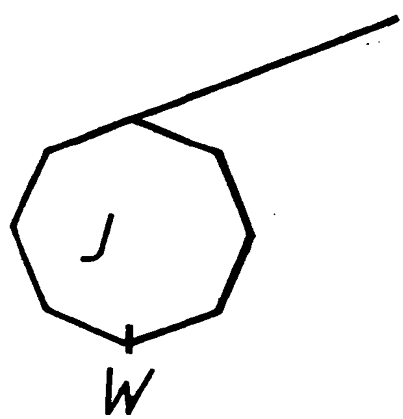


Fig.3d.



SPECIFICATION

Improvements in or relating to aircraft instrumentation

This invention relates to aircraft instrumentation and in particular to instrumentation for jet-borne flight.

In jet-borne flight a proportion of the lift required to maintain altitude is provided by engine thrust. In conventional jet-borne aircraft this is done by vectoring engine thrust at a downward angle, or providing separate vertically acting engines.

A pilot of a jet-borne aircraft is vitally concerned with power margin as this determines whether his aircraft has a hover or vertical landing capability. Power margin is defined in the art as the difference between the maximum engine power normally available or allowed, and the instantaneous engine power being used.

Hover weight is the maximum all up aircraft weight that the engine can support in a steady hover whilst maintaining the recommended safe power margin. Clearly at weights in excess of the hover weight a vertical landing cannot be performed. Hover weight can change during flight as for example fuel is used or stores deployed, so a determination of the power margin available is vital in jet-borne flight to enable a pilot to assess the current capability of his aircraft.

The limit on available power normally depends on a number of variables such as engine speed and jet pipe temperature. The variable which sets the limit on engine performance will also change with temperature, so in order to assess power margin a pilot must assimilate the critical flight parameters and perform some mental selection and arithmetic; and all at the time of highest workload when a jet-borne manoeuvre is contemplated.

According to the present invention a power margin indicator for jet-borne flight includes means for monitoring engine parameters likely to limit available power, means for scaling each monitored parameter with respect to its limiting value in the prevailing conditions to produce a thrust margin, means for comparing the thrust margins and means for displaying the thrust margin of the parameter closest to its limiting value.

Preferably the limiting value of each parameter is continuously computed as a function of ambient and operating conditions. The display may advantageously be scaled such that the margin of the parameter currently setting the limit on available power always has the same scale value and additionally an indication is provided of which parameter is setting the limit. If the maximum power limit is exceeded an excessive power indication is provided.

In a preferred form of the present invention power margin is only displayed when the margin falls below a threshold level or in certain parts of the flight envelope to provide an indication that power margin is a critical factor. The indication may be further scaled to a datum which always has the same scale value with respect to the scaled maximum.

In order that features and advantages of the present invention may be appreciated, embodiments will now be described with reference to the accompanying diagrammatic drawings, of which:

Figure 1 represents a power margin indicator,

Figure 2 represents a power margin indicator for a particular aircraft, and

Figure 3 represents example of a display format for a power margin indicator.

In a power margin indicator for a vectored thrust aircraft (Fig. 1) a thrust computer 10 monitors engine speed (RPM) 11 and engine jet pipe temperature (JPT) 12. In a vectored thrust aircraft the maximum power is likely to be limited by RPM or JPT, depending on ambient and operating conditions. Thrust computer 10 computes an actual value of thrust from known relationships between RPM, JPT and ambient air temperature 14 for the particular aircraft, and provides a thrust value output on lines 15, 16. An engine operating limit computer 17 provides outputs 18, 19 proportional to the maximum value of thrust available by computations based on known relationships between fixed parameters 100, such as the particular rating of the installed engine and changing parameters 101, such as whether full, half or no water injection to the engine is in use. Thrust outputs on outputs 18, 19 therefore are set at the limiting value of thrust available with respect to JPT or RPM respectively.

Thrust values at computer output 15, 16 and 18, 19 are not absolute, but relatively scaled so that a thrust margin, that is the difference between maximum available thrust and actual thrust, may be provided by subtractors 102 and 103 for limiting values of JPT and RPM respectively. The thrust margin values associated with each paramter are directly compared by comparator 104 and the value closest to its limiting value (that is the lower thurst margin value) passed to display generator 105 for onward transmission to pilot display unit 106. Additionally fed to display generator 105 are signals on lines 107 and 108 indicating which is the limiting parameter (eg J or R) and engine rating conditions (eg W, W/2, or O) respectively.

In order that features and advantages of the present invention may be further appreciated, an additional embodiment will now be described by way of example.

In a particular vectored thrust aircraft, maximum thrust is available at maximum RPM, which is limited by ambient air temperature (θ). The actual limiting RPM value is itself a

function of temperature. In a power margin indicator for this aircraft (Fig. 2) the RPM versus θ characteristic is stored as values in a look-up table in RPM computer 20 such that an input from an air temperature sensor 21 provides a value of the maximum RPM allowable at that temperature on output line 22. In addition to the temperature limit on RPM there is an absolute limit for the particular aircraft. This limit is different dependent upon whether water injection is selected or not. These limiting values are stored in store 23, and the appropriate limit output on line 24 in response to water injection selection 25. Limits 22, 24 are compared by comparator 26 and the overall RPM limit (ie the lower value) selected for onward transmission on line 27. Actual engine RPM 28 is measured and subtracted from the limiting RPM value in subtractor 29 to output on line 200. This scales the actual RPM value with respect to the limiting RPM value to provide an RPM margin 200.

For the particular aircraft under consideration JPT also places an overall limit on available thrust, the actual limit is dependent upon water injection selection. The limiting values are stored in store 201 and the appropriate limit passed to subtractor 202 for comparison with actual JPT 203. A JPT margin 204 scaled to its maximum value is thus provided in a way analogous to RPM margin 200.

RPM margin 200 and JPT margin 204 are suitably scaled 205, 206 for direct comparison as thrust margins 207 and 208 respectively in comparator 209. It will be appreciated that thrust margin 207 represents the margin available with respect to RPM limit 27 and thrust margin 208 the margin available with respect to JPT limit 210, hence the lower margin represents the actual margin available based on the parameter which would currently limit power. This value is output from comparator 209 and scaled 211 for onward transmission to display waveform generator 212 and pilot display unit 214 as power margin 215. Also transmitted to display waveform generator 212 is a signal 216 denoting which parameter is currently setting the limit on available power (JPT or RPM) and a signal 217 denoting water injection selection 25.

Power margin 215 is derived from thrust margin 218 by scaling 211 with respect to display datum 219 and threshold datum 220. Display datum 219 is continuously computed such that the maximum available power always has the same scaled value despite changes in the actual value. Threshold datum 220, which sets the minimum value of the scale may be varied to maintain consistency with display datum 219, or with other parameters, such as water injection selection. For the particular aircraft considered the actual thrust margin 218 is also scaled with respect to a hover power datum 221 (ie the power required to support the hover weight) such that this power always has the same scaled value.

A display format suitable for a power margin indicator has been developed in the course of making the present invention and will now be described. The embodiment considered is for head up display, but may also be suited to head down presentation.

The format is based on an octagon 30 (Fig. 3(a)) in which the display datum and threshold datum coincide at upper corner 31. This results in a complete octagon representing full available power and the display being extinguished below threshold. The format shows hover power datum 32 at lower corner 32. There is also provision for indicating the limiting parameter J or R (JPT or RPM) and water selection on (W) or off.

It will be appreciated that the format does not represent absolute values, but values relative to maximum available power, hover power and threshold as determined by the scaling previously described. It will further be appreciated that such a power margin indicator provides an easily assimilated display of power margin, without requiring a pilot assessment of absolute values or arithmetic. The format described above has been test flown and proved useful in all modes of flight, particularly during the difficult transition from conventional to jet-borne flight in a vectored thrust aircraft, and in hover and other jet-borne manoeuvres. The unmistakable indications of maximum power (Fig. 3(b)), hover power (Fig. 3(c)) and excess power (Fig. 3(d)) by extending the highest value octagon side (as a result of throttle stop trip, or engine surge) have been particularly well received in trials. In the above examples at maximum power and hover power, the display datum is set by an RPM limit, and at excess power by JPT with water injection selected in the later example. Such a straightforward display of the current capability of the aircraft has been particularly welcomed by experienced pilots of vectored thrust aircraft.

CLAIMS

The matter for which the applicant seeks protection is:

1. A power margin indicator for jet-borne flight including means for monitoring engine parameters likely to limit available power, means for scaling each monitored parameter with respect to its limiting value in the prevailing conditions to produce a thrust margin, means for comparing the thrust margins and means for displaying the thrust margin of the parameter closest to its limiting value.

2. A power margin indicator as claimed in claim 1 and wherein the limiting value of each parameter likely to limit available power is continuously computed as a function of ambient and operating conditions.

3. A power margin indicator as claimed in

claim 1 or claim 2 and including means for scaling the display such that the margin of the parameter currently setting the limit on available power always has the same scale value.

4. A power margin indicator as claimed in claim 1, 2 or claim 3 and including means for indicating which parameter is closest to its limiting value.

5. A power margin indicator as claimed in any preceding claim and including means for providing an excess power indication when the maximum power limit is exceeded.

6. A power margin indicator as claimed in any preceding claim and wherein power margin is only displayed when the margin falls below a threshold level, or during certain parts of the flight envelope.

7. A power margin indicator as claimed in any preceding claim and including means for further scaling the display to a datum which always has the same scale value with respect to the scaled maximum.

8. A power margin indicator as claimed in any preceding claim and wherein jet pipe temperature is a monitored parameter.

9. A power margin indicator as claimed in any preceding claim and wherein engine speed is a monitored parameter.

10. A power margin indicator as claimed in any preceding claim and including means for displaying engine rating conditions.

11. A power margin indicator as claimed in any preceding claim and including means for storing aircraft characteristics as look-up tables.

12. A power margin indicator as claimed in any preceding claim and wherein power margin is displayed as an octagon or part of an octagon.

13. A power margin indicator substantially as herein described with reference to the drawings.

14. Head-up display apparatus including a power margin indicator as claimed in any preceding claim.

15. An aircraft including a power margin indicator as claimed in any preceding claim.

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